STUDIES FOR STUDENTS.

THE DRIFT—ITS CHARACTERISTICS AND RELATIONSHIPS.[1]

CONTENTS.

THE TOPOGRAPHIC RELATIONS OF THE DRIFT.

The body of the drift. The drift is not confined to any topographic situation. Its vertical range may be hundreds of feet within a single mile. It occurs on the tops of mountains thousands of feet high, as well as on their slopes and at their bases. It covers hills of lesser magnitude, and mantles high plateaus and low plains with apparent indifference. It is found down to the level of the sea in some places, and is known to pass beneath it. Throughout all these topographic situations it maintains a tolerably constant character. Stratified drift often extends beyond the margin of the general drift-sheet. In such cases it is generally confined to the valleys leading out from the drift area. The stratified drift which is beyond the edge of the general drift-sheet is thus seen to maintain a definite relation to topography. As a general fact, the northern part of the drift-covered territory is higher than the southern, although elevated areas are not wanting near its southern limit.

[1] Continued from page 724.

The topographic relations of the great sheet of drift make it clear that the agencies which produced it must have been measurably independent of topography over the greater part of the drift area, but forces which were dependent upon topography carried stratified drift into valleys far beyond the borders of the area which is generally drift-covered.

Topographic terminus of the drift. Remembering that most of the drift was transported in a general southerly direction, it is a not insignificant fact that the line marking its southern boundary is largely independent of present topography. The drift does not rise to a given altitude and then fail; neither does it descend to a certain level below which it does not occur. In general, its southern boundary may be said to be lower than the larger part of the area which it covers to the north. In view of the direction in which it was transported, its distribution with relation to present topography is such as to indicate that in the process of distribution it was frequently stopped on a downward slope. The only escape from this conclusion would seem to lie in the assumption that the land surface has been extensively deformed since the drift was deposited, an assumption for which we have no warrant. In detail, the terminus of the drift is now on level lowland, now on level highland, now on a surface sloping toward the direction whence the drift came, and now on a surface sloping in the opposite direction. At some points, the terminus is found upon hilltops, while at others closely adjacent it is in the bottoms of valleys. The margin of the drift is therefore far from being horizontal. If it were allowable to suppose that the drift-covered area to the northeast had been elevated since the drift was formed, or that the driftless territory to the south had been depressed since that event, we might suppose that some more definite relationship than now appears formerly existed between altitude and topography on the one hand, and drift distribution on the other. But no general northward elevation or southward sinking will account for the topographic irregularity of the border of the drift. The character of this irregularity is such that, taken in connection with its surroundings, it is clearly not

the result of any post-drift alterations of level. The topographic irregularity of the drift border was original. It follows that the activities of the drift-producing agencies were not confined to a horizontal line along the outermost limit of their reach.

Topography of the Drift.

The topographic expression of a drift-covered country can hardly be said to be identical with the topographic expression of the drift, since the former is largely dependent on the topography of the subjacent rock. Strictly speaking, the topography of the drift is the topography which it possesses independently of its bed. It is the topography which it might assume if deposited on a plane surface. It should not be understood, however, that the topography of the underlying rock exerts no influence on the topography of the drift. Suffice it here to say that the topography of the drift varies within wide limits. Both stratified and unstratified drift may have surfaces which are nearly plane, though such surfaces are rather more characteristic of the former than of the latter. A plane surface of stratified drift is almost sure to have a slight inclination, tolerably constant both in degree and direction for any limited area. This cannot be said of the plane surfaces of unstratified drift, where such exist. By all degrees of gradation plane surfaces of either phase of drift may depart from planeness by taking on shallow depressions; but a plane topography interrupted only by depressions is much more characteristic of stratified than of unstratified drift. Again, the depressions in the surface of the stratified drift are more likely to be circular in form and more sharply defined than those in the surface of the unstratified, where such exist. In the latter case depressions are almost always accompanied by slight elevations, the counterparts of the depressions, the profiles of which are very gentle. If, along with the depressions, swells affect the surface of the stratified drift, as they sometimes do, they are likely to be more abrupt than the corresponding features of the unstratified drift. They generally have smaller bases for equal heights.

Either the stratified or the unstratified phase of drift may

have a topography of moderate relief and gentle profiles. But this is more characteristic of the unstratified than of the stratified phase. Either phase may have a rough topography, rough rather by virtue of the small size, steep slopes, and close juxtaposition of the elevations and depressions. than because of great relief. Extreme roughness of drift topography is perhaps as characteristic of certain special phases of stratified drift as of unstratified, but it is more characteristic of intimate associations of stratified and unstratified drift than of either alone.

If the average thickness of the drift be no more than one hundred feet, the average amount of relief for which it can be responsible is manifestly not great. The greater its thickness, the greater the variations of surface which it can produce, if irregularly disposed. Reliefs of one hundred feet or so, attributable to the drift alone, are not rare along certain belts of thick drift. Such differences in altitude may occur within the space of a few rods, but they do not characterize any considerable fraction of the drift-covered area. Reliefs of much greater range, belonging wholly to the drift, are seldom met with. Where so great relief occurs within narrow geographic limits, it is usually where deep, abrupt, kettle-like depressions are associated with equally abrupt hillocks.

The topography of the drift is not defined or described when its range of relief is indicated. Nothing more need be said concerning it at this point, than to indicate that one of its notable characteristics is the presence of multitudes of depressions which have no surface outlet. These depressions may have any depth up to a hundred feet or more. Reference is here made only to those depressions which affect the surface of drift, not to those for whose existence the irregularities of the surface of the underlying rock is largely or wholly responsible.

The depressions may be of any form, regular or irregular. They may be of any area, up to many square miles. Their slopes may have any degree of steepness, limited only by the angle at which loose material like the drift will lie. They may be closely grouped or widely scattered. Thousands and tens of

thousands of these depressions are marked by the swamps, ponds, and lakes of the northern part of the United States. Indeed, these features are so nearly co-extensive with the drift, that the line marking the limit of the latter may almost be said to be the line marking the limit of the former. The principal exceptions to this statement are the marshes and shallow ponds along coasts and sluggish streams outside the drift.

If it be remembered that the depressions in the surface of the drift have a wide range in the matter of area, shape, depth, and

Fig. 2. One type of drift topography. Drawn from photograph of drift surface, near Hackettstown, N. J.

abruptness of slope, a rough sort of idea of drift topography may be acquired by imagining at least an equal number of hills, of equally diverse sizes, shapes, and slopes, interspersed between the depressions. It is not to be understood that the depressions and hills are everywhere existent in the drift-covered area, or that they are everywhere striking, where they exist. It is to be remembered that there are areas of drift of great extent, the topography of which is essentially plane, and that there are other areas of equal extent where the topography is but gently rolling, and where the elevations and depressions are therefore not obtrusive. It is to be remembered further that in many parts of the drift-covered territory, the controlling element in the surface topography is

the topography of the underlying rock. Yet, in spite of all these exceptions, the presence of undrained depressions associated with elevations which, roughly speaking, are their counterparts, is one of the most distinctive features of drift topography. The topography of the drift is in sharp contrast to the topography developed by river erosion, for in regions whose surfaces are fashioned by river erosion the depressions are valleys, and each has an outlet. Every tributary valley leads to a lower, and the lowest leads to a lake, to an inland basin, or to the sea.

When the surface of the drift is rough, the roughness is dependent in part on the amount of relief, but more especially on the abruptness of the hills and hollows, and the closeness of their association areally. Where they have steep slopes and are close-set, even with but moderate relief, the topography appears rough. Where they are farther from one another, and possess gentler slopes, the topography may appear much less rough, even though the relief within broader areal limits be equally great. The topography of the drift, could it be distinctly separated from the topography of drift-covered areas, would be found to be measurably independent of the topography of the subjacent rock.

The Topography of the Drift-Covered Areas.

It is of consequence to distinguish between the topography of driftless and drift-covered territory. The topography of the latter is often, but not always, strikingly unlike that of the former. The topography of driftless territory varies within certain limits, and the topography of drift-covered territory varies within certain other limits. Sometimes the two types of topography vary toward a common limit. Under such circumstances they may closely simulate each other. In general it may be said that the most distinctive difference between the topographies of drift and driftless areas is the more perfect and more systematic development of the drainage lines upon the latter. This is made obvious in one way by the abundance of marshes, ponds, and lakes in the drift area, in contrast with their scarcity without.

It is made obvious in another way by the definite and systematic relations which exist between the elevations and depressions. In non-mountainous driftless regions, the depressions are usually river valleys, and the elevations inter-stream ridges. The common relationship of these features is such as to show that the inter-stream ridges are but remnants of a surface which has been roughened by the excavation of the valleys. In the drift-covered areas, on the other hand, this relationship does not always exist, and even where it can be made out, it is often obscure.

It is also of consequence to distinguish between the topography of drift-covered areas and the topography of the drift. The topography of the drift, it will be remembered, is the topography which it possesses independently of its bed. It is the topography which it might have if deposited on a plane surface. The topography of drift-covered areas is due partly to the topography of the drift *per se*, and partly to the topography of the rock below the drift. Either one of these elements may be the controlling one. Where the drift is thin and uniformly distributed, the topography of the drift-covered territory corresponds closely with that of the rock beneath. Where the drift is thick and irregularly disposed, the topography of the area it covers may be very unlike that of the subjacent rock. In extreme cases, and for limited areas, the drift may be so thick and so irregularly disposed that the surface affected by it preserves none of the topographic features of the underlying rock. In any case the existing topography is the resultant of the two elements. If the topography of the underlying rock has a relief greater than the average thickness of the drift, it will still determine the larger features of the resultant topography, though perhaps not its details. If the topography of the underlying rock possesses a relief which is slight in comparison with the average thickness of the drift, the latter may determine both the major and minor features of the resultant topography.

The drift and drift-free surfaces present many differences. Where there is no drift the valleys are likely to be more nearly straight. Here, too, the tributary valleys join their mains in a more regular way, and at a more nearly uniform angle, forming

more symmetrical systems. Abrupt turns and striking detours of streams are, on the whole, less frequent,[1] though this is not illustrated by limited areas everywhere. Within the drift area of North America, rapids, falls, and other evidences of youthful drainage are much more common than in adjacent driftless areas of comparable altitudes. The elevations between the valleys are more continuous in the driftless areas, unless the drainage system is so far advanced in its life-history as to have notched the inter-stream ridges, or to have cut them into isolated hills. The elevations and valleys stand in more definite and constant relations to each other; that is, the topography of the driftless country is a topography the details of which have been fashioned mainly by running water.

If it be true, as, on the whole, it probably is, that the drift territory has less relief than the driftless for corresponding altitudes, it is also true that its surface is often more "choppy," the hills being shorter and more noticeably huddled together. This characteristic is popularly recognized in such names as "short hills," "knobs,"[2] etc., names which have been locally used because of the striking contrast in shape between the discontinuous hills of drift, and the associated hills of greater length composed of solid rock (see Fig. 2). The choppiness of surface is by no means co-extensive with the drift. Where it is present, the drift, rather than the underlying rock, is the controlling element in the present topography. Drift hills are sometimes low and symmetrical in form, and their slopes gentle. They are sometimes more or less systematic in arrangement over considerable areas, but even then their forms do not generally stand in any definite relation to river valleys. Hills which are only drift-coated may bear a more or less obvious relation to the valleys, but hills composed entirely of drift are measurably independent of them.

[1] The abrupt turns of streams in their flood plains is not here taken into account.

[2] The name "Short Hills" has been given to a village in New Jersey where the surface is of the character here referred to. The term "knobs" is frequently applied to the abrupt and closely set drift hillocks. This term has also been popularly used in other relations to designate a very different type of topography.

In some regions, and over considerable areas, river erosion has so far modified the topography developed at the time of deposition of the drift as to reproduce a topography comparable in kind to that which affected the subjacent rock before the drift was deposited. In this case the characteristic features of drift topography have been destroyed. River erosion topography has been superimposed on the topography of the drift-covered area. Ridges and hills fashioned by streams working upon the drift, stand in that relationship to adjacent valleys which the laws of stream erosion determine.

Plane tracts may be brought into existence in very different ways. They occur in driftless as well as in drift-covered areas, Flatness, therefore, cannot be regarded as diagnostic, either of drift or of driftless regions.

It follows from the foregoing that the drift forces must have been such as were able to develop plane surfaces at some points, surfaces marked by more or less symmetrical drift hills which are measurably independent of valleys at others, and short, choppy hills, in still others. They must have been such as were able to modify, to all degrees, the pre-existent rock topography.

Relation of Drift to the Underlying Rock.

Where fresh exposures show the contact between any considerable bed of drift and the underlying rock, it may be seen that the drift does not generally grade into the rock. Especially where the underlying rock is hard, the plane of contact between it and the drift is generally sharply marked. Where the underlying rock is not indurated, the plane of contact is sometimes less well defined. Furthermore, where the underlying rock is hard, its surface is commonly firm and fresh. Signs of weathering are absent. Any weathered surface it may once have had before the drift was deposited was completely removed during that process. This relationship is shown in the accompanying diagram (Figure 3). It should not be inferred that the relationship between the drift and the underlying rock expressed in the diagram is universal, even where the drift is thick. It frequently does not

obtain where it is too thin to protect the rock beneath from considerable changes of temperature, and from the effects of those other disintegrating agencies which affect the surface to a depth of a half dozen feet. In such situations the surface of the

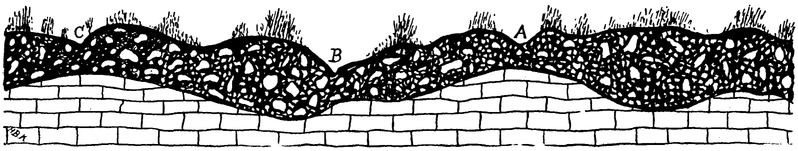

Fig. 3, illustrating the relation of drift to underlying rock. The line of contact is distinct, and the rock surface is not roughened by decay.

underlying rock may be much broken and weathered. If the rock be of such a character as to successfully resist weathering, its surface may be smooth and firm where the thickness of drift is very slight, or even where it is altogether absent.

The relation which the drift sustains to its underlying rock bed is therefore distinctly unlike that which the residuary earths of driftless regions sustain to the rock upon which they rest. In the latter case, as the designation "residuary earth" implies, the soil and subsoil have arisen chiefly from the decomposition and disruption of the underlying rock. All rock beds lack homogeneity to such an extent that their surfaces weather unequally. Their weathered surfaces are therefore uneven. The weathered

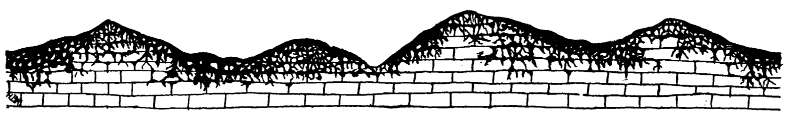

Fig. 4 shows relation of soil to rock, where the former has arisen by the decay of the latter. The line of contact is indefinite because of the irregular decay of the rock surface.

product of the rock—the subsoil—fills the little hollows on its surface, and penetrates the fissures and cracks, while the prominences of the uneven rock surface project up into the subsoil. The relationship referred to is illustrated in Figure 4, where the upper darker portion represents the residuary earths, and the lighter part

below the underlying rock whence the earths were derived. As shown in the figure, the upper surface of the rock is often so much broken, and so much mingled with the more earthy subsoil, as to make it very difficult to locate the plane of contact between them.

The true theory of the drift must explain its relation to the rock beneath. Any hypothesis which fails to explain this relationship must be incomplete at the very least. Any hypothesis with which this relationship is inconsistent, must be false.

Significant Features of the Surface of the Rock Underlying the Drift.

Striation and planation of the bed rock. Besides the characteristics referred to in the last paragraph, the rock surface beneath the drift, and especially beneath the unstratified drift, is frequently found to be polished and striated. Sometimes it is polished without being striated, but the two things usually go together. While these features are found at many points throughout the drift-covered area, and at all elevations at which drift occurs, they are not found everywhere where there is drift, and are rarely found beyond its limits. Where similar striæ on bed rock are found outside the limits of the great drift area, it is not without significance that they occur in lesser areas of drift. In North America, these lesser bodies of drift, with their striated stones, and with striated bed rock beneath, are in the lofty mountain regions of the west. The smoothings and the markings on the bed rock beneath the drift are identical in kind with those already noted as occurring on the bowlders of the drift. So exact is the correspondence, that community of origin cannot be doubted. The drift agencies, therefore, must have been capable of striating the rock beneath the drift, as well as the stony materials of the drift itself.

The striæ on the bed rock beneath the drift are generally approximately parallel in any given locality, and tolerably constant in direction over considerable areas. In a general way, the direction of striæ corresponds with the direction in which the drift has been transported. When large areas are studied, the

striæ are sometimes found to be far from parallel. Less commonly, this is true for small areas. Divergent and inharmonious as these various directions sometimes seem to be, fuller knowledge discovers a system in their arrangement. In many areas, the striæ are found to arrange themselves in systems. Within each system the striæ are found to be divergent from a common axis. Such axis is not generally a mountain range, or even a ridge. It is oftener a broad valley.

The systematic arrangement of the striæ, as developed in some regions, is illustrated by the accompanying figure (Figure 5), which represents, in a diagrammatic way, the arrangement of striæ on the rock surface beneath the drift of eastern Wisconsin. The striæ on the right-hand side of the figure appear to represent the marginal part of a second system, the axis of which is in the trough of Lake Michigan. In other localities, also, two similar systems of striæ lie side by side.

Within any single divergent system there may be local divergences from the common direction. In such cases, the divergences are almost uniformly associated with local topographic features. The striæ often have such a direction as to indicate that the agent which made them had a tendency to go around a hill or ridge, instead of passing directly over it. This tendency of striæ to veer round elevations may sometimes be observed about large and abrupt hills, while in the same locality lower hills with gentler slopes do not appear to have influenced the course of the striating agent.

Striæ are not confined to horizontal or gently inclined surfaces. They sometimes occur on steep slopes, on the vertical faces of cliffs, and, occasionally, even on the under side of overhanging rock masses. They sometimes occur in still more anomalous positions. In the face of the high bluff overlooking Cayuga Lake, for example, a horizontal groove in a vertical face is striated on its upper, lower, and interior sides. The groove in which the striæ occur retires eight inches into the face of the vertical cliff.[1]

Where striæ are absent from the surface of the rock beneath

[1] Seventh Annual Report, U. S. Geol. Survey, pp. 170, 173.

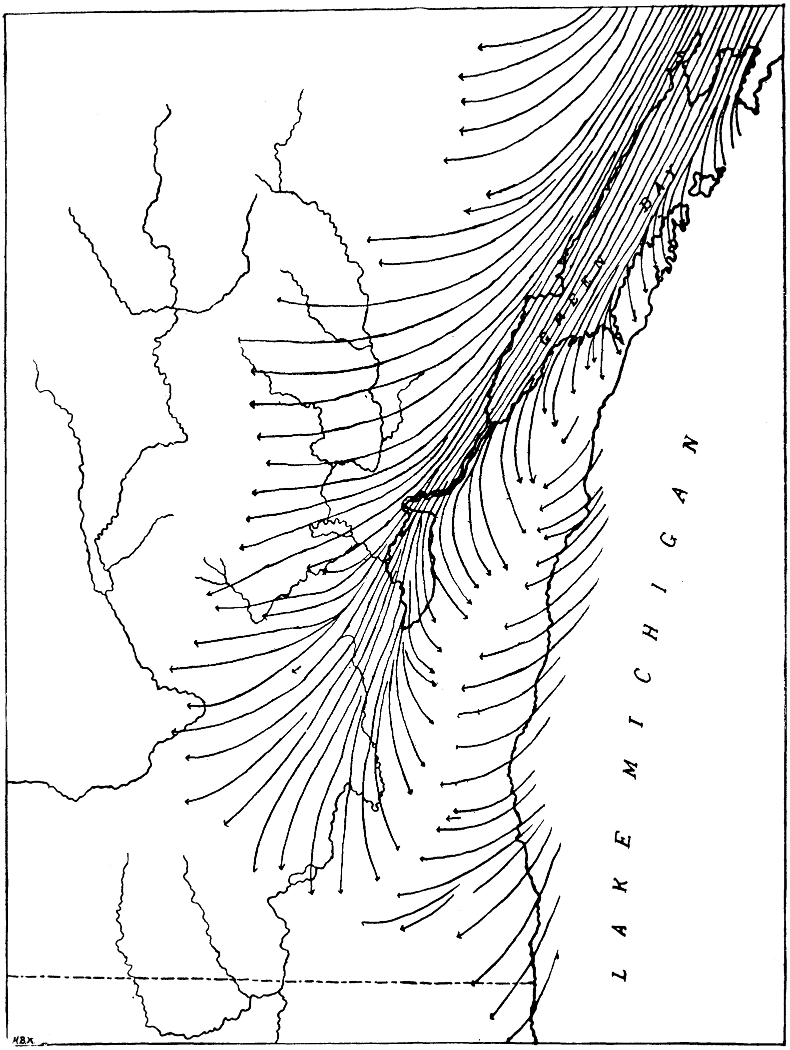

FIG. 5. Illustrating the general arrangement of striæ in Eastern Wisconsin.

the drift, their absence must be due to one of two things; either they were never formed, or they have been destroyed. Where the character of the underlying formation is such as to unfit it for receiving striæ, they could never have been developed. This would be true where the underlying formation is loose sand or gravel. Where the underlying rock is such as not to favor the development of striæ, but not such as to prevent their formation altogether, they may be rare. This might be true of rock which is unusually hard, and for this reason difficult of striation, or it might be true of rock which is very fragile and easily crushed. Where the underlying rock is ill-adapted for retaining striæ, they could not be expected to remain in great numbers, even if once developed. This would be the case where the rock is plastic, like clay, or where the rock is readily disintegrated. Again, striæ which once existed on rock adapted to receiving and retaining them may have been destroyed because of adverse conditions. Thus limestone received and has preserved striæ quite as well as any formation where the striated surface has remained deeply covered with drift. Where little or no covering has protected it, the striæ are absent, or ill-defined. It is reasonable to suppose that such surfaces were once striated, but that weathering has destroyed the marks.

The foregoing considerations help to explain why the striæ are not found at all points beneath the drift, even if the drift agencies and the polishing and striating agencies were the same, as we must believe they were. But there are places, and not a few of them, where striæ and polishing do not appear to have existed, even though the bed rock is of such a nature as to have favored their development and retention. In such cases the drift is often seen to rest, not on the solid rock, but on a layer of residuary material which originated in the decomposition of rock beneath. In this case the immediate substratum of the drift is really an incoherent earth, incapable of receiving striæ. In other areas where striæ and polishing are not known, their absence is probably apparent only. This is true in regions where the rock is so deeply buried that it is rarely seen.

Any acceptable theory of the drift must account for the divergent systems of striæ, for the local deflections from the general direction within these systems, and for the association of such deflections with local topographic features. It must also account for the occurrence of striæ on steep slopes, on vertical faces, on the under side of overhanging rock masses, and on the lower, upper, and interior surfaces of horizontal grooves in vertical cliff faces. It must be consistent with the absence of striæ and polishing on the rock surface at many points within the drift-covered territory, and must be mindful of the absence of the same sort of markings on the surface of the rock formations outside the drift. The phenomena of the striæ show that the drift agent or agents, or some of them, must have been such as could, under some circumstances, work with a large measure of independence of topography, at the same time that they were, under other conditions, locally influenced or even largely controlled by it. They must have been such as could have sometimes operated at great altitudes, as in the mountains of the west, without affecting the lower levels surrounding.

The shape of the rock hills projecting through the drift. In many places within the drift-covered area, but not everywhere, the rock knobs which project through the drift, or which are but slightly covered by it, possess certain characteristics which are not without significance. Such bosses of rock frequently have smoothed and rounded forms which are so distinctive that they have received a special name, *roches moutonnées*. In some regions each rock-prominence seems to be a *roche moutonnée*. In such cases, one side of each boss seems to be worn more than the others, and in any limited area it is generally the same side of each hill which shows the greatest wear. This fact must be taken into account in any attempt to explain the drift, for it is a phenomenon about as widely distributed as the drift itself, though not by any means to be seen at all points. The sides which are most worn are those facing the direction from which the drift forces moved, as shown by the direction of striæ, and by the direction in which material has been transported.

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(To be continued.)